Bose gases quenched to unitarity

Zoran Hadzibabic
University of Cambridge

Thursday, 14:00-14:45 (invited talk)

I will give an overview of our recent progress in trying to understand the dynamics and thermodynamics of a Bose gas quenched to unitarity. We have performed a series of experiments with both degenerate and thermal gases, and obtained measurements of the three-body contact, the universal scalings in the decay dynamics at unitarity, and most recently of the energy and quantum depletion of the degenerate unitary Bose gas.

Harnessing electro-optic correlations to improve an efficient mechanical converter

Peter Burns
University of Colorado

Thursday, 14:45-15:30 (invited talk)

A mechanical link between superconducting circuits and the optical domain is an appealing route to a large-scale quantum network. We show that vibrational noise -- ubiquitously introduced by such a link -- can be overcome by harnessing microwave-optical correlations. We construct a microwave-mechanical-optical converter operating at 100 mK, and demonstrate an unprecedented conversion efficiency of 47%. Discovering that vibrational noise produces correlations between microwave and optical outputs, we implement a classical feedforward protocol that improves the recovery of a weak, upconverted signal and reduces noise by 59%, to 38 photons of added noise, for this high-efficiency device. Our results introduce an intriguing alternative method for handling errors introduced by thermal noise.

Single phonon control and remote entanglement of mechanical resonators

Ralf Riedinger
University of Vienna

Thursday, 15:30-15:50

Mechanical memory elements, directly coupled to photons at designed telecom wavelengths possess many advantageous features as nodes for large area quantum networks. Yet, while impressive experiments on ground state cooling and phonon lasing have recently been demonstrated, genuine non-Gaussian optical quantum control remained elusive. Here we report on the optical generation of single phonon Fock states and remote entanglement of two mechanical oscillators, using so-called optomechanical crystals. We thereby add a silicon photonics based alternative to the pool of resources for future quantum communication endeavors.

Thermal Baths Under Control: More Friends than Foes

Gershon Kurizki
Weizmann Institute of Science

Thursday, 16:30-17:15 (invited talk)

I will review our past and ongoing research regarding the ability of thermal reservoirs (baths) to act, under appropriate control, as resources for (i) quantum sensing (noise spectroscopy and thermometry by quantum probes), (ii) long - range entanglement between dipoles induced by virtual quanta exchange via the bath, and (iii) cooling of oscillator and spin baths. The baths play an essential role in all of the above processes. Hence, thermal baths may be much more friends than foes.

Cavity quantum electrodynamics in the non-perturbative regime

Daniele De Bernardis
TU Wien

Thursday, 17:15-17:35

We study a generic cavity-QED system where a set of (artificial) two-level dipoles is coupled to the electric field of a single-mode LC resonator. This setup is used to derive a minimal quantum mechanical model for cavity QED, which accounts for both dipole-field and direct dipole-dipole interactions. The model is applicable for arbitrary coupling strengths and allows us to extend the usual Dicke model into the non-perturbative regime of QED, where the dipole-field interaction can be associated with an effective finestructure constant of order unity. In this regime, we identify three distinct classes of normal, superradiant and subradiant vacuum states and discuss their characteristic properties and the transitions between them. Our findings reconcile many of the previous, often contradictory predictions in this field and establish a common theoretical framework to describe ultrastrong coupling phenomena in a diverse range of cavity-QED platforms.

Superradiant Hybrid Quantum Devices

Andreas Angerer
TU Wien

Thursday, 17:35-17:55

Superradiance is the archetypical collective phenomenon where radiation is amplified by the coherence of emitters. It plays a prominent role in quantum optics as one of the most studied non-linear effects and enables the implementation of quantum technologies such as the design of lasers with substantially reduced linewidths. In this talk we present superradiance in a hybrid system composed of a 3D lumped element resonator in the fast cavity limit inductively coupled to an inhomogeneously broadened ensemble of nitrogen-vacancy (NV) centres. We observe a superradiant pulse being emitted from the cavity a trillion of times faster than the decay for an individual NV centre, and the typical non-linear scaling of the emitted radiation intensity with respect to the ensemble size; both indicators for the superradiant nature of the emitted light.

Optical Nanofibers; some experiments in optomechanics and quantum optics with them

Luis Orozco
University of Maryland

Friday, 09:30-10:15 (invited talk)

Nanofibers produced by tapering an ordinary single mode optical fiber to diameters of half a micron are interesting optical objects. We have studied the Spin-optomechanical coupling between light and a nanofiber torsional mode with nanofibers excited with circularly polarized light in the HE11 mode. Our recent experiments with cold Rb atoms around the nanofiber include the modification of the lifetime of the D2 line in the presence of the nanofiber and its relation to the single atom coupling. We find modifications of the lifetime that depend on the alignment of the dipole with respect to the nanofiber: parallel or perpendicular. We also explore the asymmetry on the absorption spectrum of atoms near the nanofiber.

Will a decaying atom feel a friction force?

Matthias Sonnleitner
Universität Innsbruck

Friday, 10:15-10:35

We show how a simple calculation on textbook level leads to the surprising result, that an excited two-level atom moving through vacuum sees a (tiny) friction force in first order v/c. At first sight this seems to be in obvious contradiction to other calculations showing that the interaction with the vacuum does not change the velocity of an atom. Even worse, it appears to be in contradiction to the principle of relativity. It is thus even more surprising that this change in the atom's momentum turns out to be a necessary result of energy and momentum conservation in special relativity.

The influence of spacetime curvature on quantum emission in optical analogues to gravity

Maxime Jacquet
University of Vienna

Friday, 10:35-10:55

Quantum vacuum fluctuations on curved spacetimes cause the emission of entangled pairs. The most remarkable instance of this effect is Hawking radiation from black hole horizons, which can however not be observed in astrophysics. Fortunately, it is possible to recreate the kinematics of waves on curved spacetimes in the laboratory to study horizon emission. Here we investigate and demonstrate the role of laboratory horizons for the production of entangled pairs. We develop a field theoretical description based on an optical analogue system in the Hopfield model to calculate the scattering matrix that completely describes mode coupling leading to the emission of pairs in various kinematic configurations. We find that horizons lead to an order of magnitude increase in the pair production, a simplification and increase of the quantum correlations, and a characteristic shape of the emission spectrum. The findings clarify a number of open questions towards the detection of the Hawking effect in these dispersive systems. Furthermore, they will be relevant in numerous optical and non-optical systems exhibiting horizons.

Atomtronics with a spin: statistics of spin transport and non-equilibrium orthogonality catastrophe in cold quantum gases

Michael Knap
TU München

Friday, 11:30-11:50 (invited talk)

Recently there has been significant progress in controlling and manipulating quantum impurities in ultracold quantum gases. We propose the realization of a spintronic device using ultracold quantum gases, which makes it possible to study the full counting statistics of non-equilibrium spin transport. We show that the counting statistics is tuned from a conventional binomial distribution to an unconventional distribution when increasing the scattering length. We will also discuss the relations to the non-equilibrium orthogonality catastrophe.

Spin Squeezing and many-body entanglement quantification with uncertainty relations

Giuseppe Vitagliano
IQOQI Vienna

Friday, 11:50-12:10

We present general methods on how to derive entanglement criteria based on local uncertainty relations and review our recent results applied to entanglement detection in many-body ensembles (e.g., 10^3-10^12) of cold and ultra-cold atoms (BECs). We show how the original spin squeezing approach can be generalized in several respects and how it allows to quantify entanglement by means of the so-called depth of entanglement. Furthermore, we present particular examples of criteria that has been recently applied to detect the depth of entanglement in (i) unpolarized Dicke states, produced dynamically in a Rb BEC [1,2]; (ii) Planar Quantum Squeezed states, produced with Quantum-Non-Demolition measurements in a Rb atomic cloud [3]. In such states the depth of entanglement has been also shown to be directly related to the performance of the state in phase estimations with quantum resources, leading to an improvement over the classical shot-noise limit. Finally, we present an EPR-like criterion tailored to detect entanglement in a Dicke state split in two spatially separated modes [4], analogous to continuous-variable criteria but tailored for finite, high-dimensional spin systems.

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[2] G.Vitagliano, I.Apellaniz, M.Kleinmann, B. Lücke, C.Klempt, and G.Toth. Entanglement and extreme spin squeezing of unpolarized states. New J. Phys., 19, 2017.

[3] G. Vitagliano, G. Colangelo, F. Martin Ciurana, M. W. Mitchell, R. J. Sewell and G. Tóth, Entanglement and extreme planar spin squeezing, Phys. Rev. A 97, 020301(R) (2018)

[4] K. Lange, J. Peise, B. Lücke, I. Kruse, G. Vitagliano, I. Apellaniz, M. Kleinmann, G. Toth, C. Klempt, Entanglement between two spatially separated atomic modes, arXiv:1708.02480 (to appear in Science)

Renyi entropies from random measurements in a trapped ion quantum simulator

Andreas Elben/Petar Jurcevic
University of Innsbruck, IQOQI Innsbruck

Friday, 12:10-12:45

Recently, the use of random measurements has been proposed to infer Renyi entropies in atomic quantum simulators from single instances of quantum states [1,2]. Whereas the required random unitary operations can in general to be implemented using interacting many-body Hamiltonians and quenched disorder, we present in this talk theory and experimental demonstration of a variant of the protocol requiring only (random) single qubit operations. With the developed scheme we measure in a trapped ion quantum simulator the 2nd order Renyi entropy of arbitrary (reduced) quantum states in a 10-qubit system - a size inaccessible with state-of-the-art quantum state tomography. This enables us on the one hand to validate our quantum simulator by quantifying the influence of decoherence. On the other hand, we demonstrate the generation of bipartite entanglement under quenched time-evolution governed by a long-range interacting spin-spin Hamiltonian, with and without controlled disorder. The clear reduction of entropy growth due to disorder reveals thereby the onset of many-body localization. As a proof-of-principle application of this scheme, demonstrating the prospects of application of our method in larger many-body systems, we further measure the time evolution of the half-chain entropy in a system of 20 qubits after a quench. Beyond Renyi entropies of many-body quantum states, we propose as an outlook how random measurements could further be used to quantify dynamics of quantum operators such as out-of-time-order correlators.

[1] S. J. van Enk and C. W. J. Beenakker, Phys. Rev. Lett. 108, 110503 (2012).

[2] A. Elben, B. Vermersch, M. Dalmonte, J.I. Cirac, and P. Zoller, Phys. Rev. Lett. 120, 050406 (2018).